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ELECTRONICS | ORIGINAL ARTICLE

Closed Loop Quasi-Orthogonal STBC for Multiple Transmitters and Multiple Receivers

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ABSTRACT

This paper presents how to design Quasi-Orthogonal Space Time Block Coding for multiple transmitting antennas and one receiver with feedback. Multipath wireless environment creates difficulty because of diversity at multiple receivers and multiple transmitters. Diversity is reduced by using Quasi-Orthogonal STBC. For simplicity we considered four transmitters and one receiver. The diversity is achieved by reducing the non-zero off diagonal terms of quasi orthogonal matrix and by reducing the number of phase rotations at the transmitter. The phase rotations are achieved by single phase and two phase methods with low number of feedback bits. In this paper We concluded that two bit feedback is better than three bit feedback which is achieved by calculation of BER (bit error rate). These techniques are effective over fading channels and indoor wireless networks with low data rate systems .with this method we can achieve low-complexity and full diversity.

Keywords: Full diversity, Space time Block Codes, Bit Error Rate. Phase feedback method.

I. INTRODUCTION

Severe attenuation in a multipath wireless environment creates extreme difficulty for the receiver to determine the transmitted signal unless the receiver is provided with some form of diversity. Such diversity can be achieved by deploying multiple antennas at the transmitter and/or the receiver. Multiple antenna techniques have been of great interest in recent times, because of their ability to support higher date rates than single-antenna systems. It is generally impractical to deploy multiple antennas at the receiver because receivers should be small. Quasi-Orthogonal STBC proposed by Papadias [6], and independently by Jafarkhani [8] for the enhancement of link layer performance has a number of features such as it enables a significant portion of the open loop channel capacity and it requires simple receiver processing. In the case of quasi-orthogonal four transmit and one receive antenna, diversity gain decreases due to non-zero ortho diagonal elements in matrix .In this paper we investigate two transmitter preprocessing schemes to orthogonalize the QO-STBC proposed by Toker[4]. A phase feedback method is used to rotate the transmitted signals from certain antennas in a prescribed way based upon partial transmitter channel state information (CSI), which is fed back from the transmitter. The rest of the paper is organized as follows:

II. QUASI-ORTHOGONAL STBC

Orthogonal Space-Time Block coding is a transmit diversity method that has the potential to enhance the forward capacity. A quasi orthogonal code could provide full code rate, but at the expense of loss in diversity. This extended to construct the code for four data symbols is as follows

$$x_{quasi} = \begin{bmatrix} x_1 & x_2 & x_3 & x_4^* \\ -x_2^* & -x_2^* & -x_4^* & x_3^* \\ -x_3^* & x_4^* & x_1^* & x_2^* \\ x_4 & -x_3 & -x_2 & x_1 \end{bmatrix} \qquad (1)$$

The code rate is

$$\begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \end{bmatrix} = \begin{bmatrix} x_1 & x_2 & x_3 & x_4^* \\ -x_2^* & -x_2 & -x_4^* & x_3^* \\ -x_3^* & x_4^* & x_1^* & x_2^* \\ x_4 & -x_3 & -x_2 & x_1 \end{bmatrix} \begin{bmatrix} h_1 \\ h_2 \\ h_3 \\ h_4 \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \end{bmatrix} \quad (2)$$

For simplicity, considering four transmitters and one receiver in a flat fading environment, by taking the complex conjugate of the second and third row of the matrix (2).the received signal vector can be written explicitly in terms of the transmitted symbols as follows

$$\begin{bmatrix} r_1 \\ r_2^* \\ r_3^* \\ r_4 \end{bmatrix} = \begin{bmatrix} h_1 & h_2 & h_3 & h_4 \\ h_2^* & -h_1^* & h_4^* & -h_3^* \\ -h_3^* & -h_1^* & -h_1^* & -h_2^* \\ h_4 & -h_3 & -h_2 & h_2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2^* \\ v_3^* \\ v_4 \end{bmatrix} \quad (3)$$

$$r_1 = h_1 x_1 + h_2 x_2 + h_3 x_3 + v_1$$
$$r_2^* = h_2^* x_1 + h_1^* x_2 + h_4^* x_3 + v_2^*$$
$$r_3^* = h_3^* x_1 + h_4^* x_2 - h_1 x_3 + v_3^*$$
$$r_4 = h_4 x_1 - h_3 x_2 - h_2 x_3 + v_4$$
$$r = Hx + v \quad (4)$$

where h_i and v_i ,i=1; 2; 3; 4 are the complex channel impulse response coefficients and zero-mean, circularly symmetric, complex valued Gaussian noise terms with variance $\sigma^2{}_n$

$$\alpha = |Re\{h_1^* h_4 - \; h_2^* h_3\}| \quad (5)$$

Respectively. Matched filtering is performed by pre multiplying by H^H, therefore we get Matched filtering is performed by pre multiplying by H^H, therefore we get

$$H^H r = H^H H x + H^H v \quad (6)$$
$$\check{r} = \Delta x + \check{n} \quad (7)$$

where$(.)^H$ represents Hermitian transpose in equation

$$\Delta = \begin{bmatrix} \gamma & 0 & 0 & \alpha \\ 0 & \gamma & 0 & \alpha \\ 0 & -\alpha & \gamma & 0 \\ \alpha & 0 & 0 & \gamma \end{bmatrix} \quad (8)$$

After match filtering at the receiver some non-zero off diagonal terms exist which reduce the diversity gain of the code. For example, the fourth symbol interferes with the first symbol, the second symbol interferes with the third symbol.

Where

$$\gamma = |h_1^2| + |h_2^2| + |h_3^2| + |h_4^2| \quad (9)$$

and

$$\alpha = Re\{h_1^* h_4 - |h_2^* h_3\},\text{Re} \quad (10)$$

Denotes the real operator.

III.ORTHOGONALIZATION BY PHASE FEEDBACKMETHOD

The non-zero ortho-diagonal elements in matrix (2) reduce the diversity gain and the signal-to-noise ratio (SNR) at the receiver. The signals transmitted from certain antennas can be modified by rotating with proper phase angle such that the magnitude of the ortho diagonal elements α is minimized.

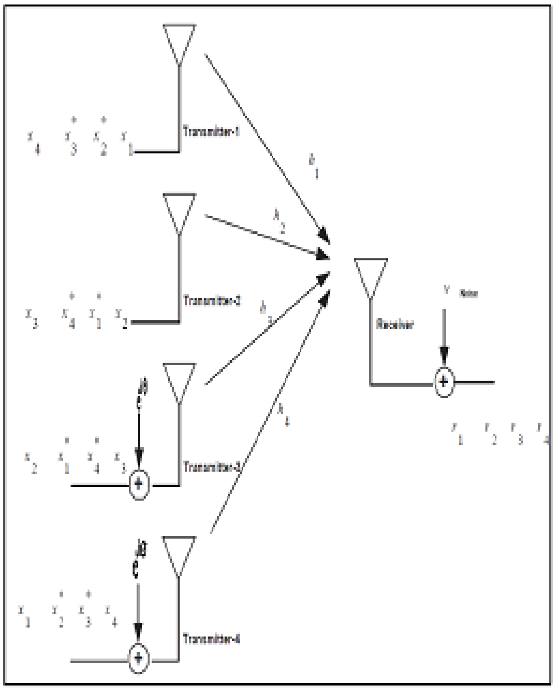

Fig 1: Four transmit and one receive antennas, showing the fading Channel coefficients and the additive white Gaussian noise

IV.TWO PHASE FEEDBACK

If the first and second terms in the brackets in equation (3) are multiplied by a phasor, it is possible to make α zero .Assuming that the signals from the third and fourth antennas are rotated by µ and Á respectively, which is equivalent to multiplying the

first and second term in equation (11) by $e^{-j\theta}$ and $e^{-j\phi}$ respectively

$$\alpha = \left|Re\{h_1^* h_4 e^{-j\theta} - h_2 h_3 e^{-j\phi}\}\right| \quad (11)$$

Let $k = h_1^* h_4$ and $\lambda = h_2^* h_3$

$$\alpha = |k| \cos(\theta + |\angle k) - |\lambda| \cos(\theta + \angle \lambda) \quad (12)$$

where j:j and L denote the absolute value and the angle (arctan) operators,respectively. Since $\alpha = 0$ has infinite solutions for Θ and ∅ The solutions

$$\theta = \arccos(\tfrac{\lambda}{k} \cos(\theta + |\angle \lambda)) - \angle k \quad (13)$$

Provided that

$$\varphi \epsilon \begin{cases} (0.2\pi) & where\ \lambda < k \\ (\pi - \xi - \angle \lambda, \xi - \angle \lambda) & \\ (2\pi - \xi - \angle \lambda, \pi + \xi - \angle \lambda, \text{otherwise} & \end{cases} \quad (14)$$

Where

$\xi = arc\ cos(|k||\lambda)$

where l .land L denote the absolute value and the angle (arctan) operators, respectively. Since $\alpha = 0$ has infinite solutions for Θ and∅ The solutions are

$$\theta = arc\ cos\left((\lambda|k) \cos(\phi|\angle \lambda)\right) \quad (15)$$

Provided that

$$\varphi \epsilon \begin{cases} (0.2\pi) & where\ \lambda < k \\ (\pi - \xi - \angle \lambda, \xi - \angle \lambda) & \\ (2\pi - \xi - \angle \lambda, \pi + \xi - \angle \lambda, \text{otherwise} & \end{cases} \quad (16)$$

where $\xi = arc\ cos(|k|\|\lambda|)$

V.SINGLE PHASE FEEDBACK

The number of feedback bits required from the receiver to the transmitter has to be small because of practical constraints. Reduction in feedback bits can be achieved by reducing the number of phase rotations at the transmitter antennas. There are two methods proposed by Taker [10], [11]

Which are as follows?

1. one way to reduce the amount of information needed to be fed back is to rotate the signal of one antenna only.
2. Another way is to quantize the feedback phase information according to the number of feedback bits available. It is possible to reduce the off diagonal terms of the matrix .just by rotating a single antenna instead of rotating two antennas. For example rotations applied only at the fourth antenna, the coupling term α can be rewritten as

$$\alpha = \left|Re\{h_1^* h_4 e^{-j\theta} - |h_2^* h_3\}\right| \quad (17)$$

$$= |k| \cos(\theta|\angle k) - \lambda_{real}$$

Where $K = h_1^* h_4$, $\lambda = h_2^* h_3$, λ_{real} (18)

Is the real part of λ and l k l is the absolute value from the above equation it is clear that the cosine wave is a function of θ scaled by l k l, phase shifted by Lk and biased by λ_{real} under the condition

$|\lambda_{real}| \leq |k|, \alpha = 0$

has two solutions for

$$\theta\ \theta_1 = arc\ cos(\lambda_{real}||k|) - \angle k$$
$$\theta_1 = -arc\ cos(\lambda_{real}||k|) - \angle k \quad (19)$$

On the other hand, if $|\lambda_{real}| > |k|$ there is no solution for $\alpha = 0$ and l α l can only be minimized at the following phase value

$$\Phi = \{-\angle k \quad |\lambda_{real}| > |k|,\}$$
$$\Phi = \{\pi - \angle k\ , -|\lambda_{real}| > |k|,\}$$

With the minimum value

$$\alpha = \begin{cases} -\lambda_{real} + |k| & , |\lambda_{real}| > |k| \\ -\lambda_{real} - |k| & , |\lambda_{real}| > |k| \end{cases} \quad (20)$$

VI. QUANTIZATION

In practice only a finite number of bits is allowed for the feedback, which we assume to equal to P bits. For the single antenna phase adjustment, the discrete estimated feedback formation corresponding to the phase μ will be

an element of the set $\theta \in \Omega = \frac{2\pi n}{2^p}, 2^p - 1$

$\theta = \text{argmin}\left((h_1^* h_4 e^{-j\theta}| - h_2^* h_3\right)$

Similarly, for the dual antenna phase adjustment, the discrete estimated feed-back information for the phases θ and φ are the elements of the set

$(\widetilde{\theta},\phi)\epsilon\Omega\frac{2\pi n}{2^{p-1}}$,n=0,1,2,3…….$2^p - 1$

and are computed as

$$(\widetilde{\theta},\phi) = argmin\left(\left(\sum_{m=1}^{n_R}(h_1^* h_4)\right)e^{i\theta}\right)-\left(\left(\sum_{m=1}^{n_R}(h_2^* h_3)\right)(e^{i\phi})\right) \quad (21)$$

VII. SIMULATION AND RESULTS

The results depicted in Figure are a comparison between the open loop quasi-orthogonal four transmit and one receives antennas and closed loop quasi-orthogonal four transmit and one receives antennas. A Rayleigh fading channel is used for simulation and it can be seen that at a BER of 10^{-3}; the performance improvement of the feedback scheme is approximately 2:53dBcompared to the open loop scheme. The feedback method is successful in reducing the ortho-diagonal terms of the matrix shows both the one phase feedback method and two phase feedback method. It is observed that the performance gain between the three bit feedback and the two bit feedback is only 0:43dB, so to use 2 bit feedback appears to be good. Due to practical limitations, a finite number of bits is allowed for the feedback.

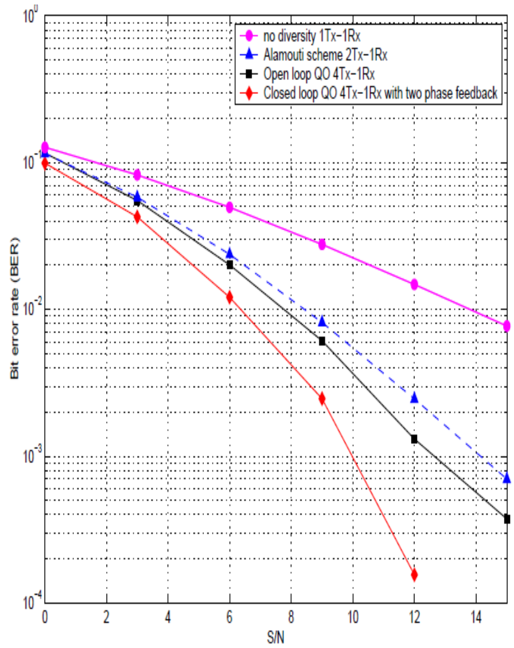

Fig 2: The BER performance comparisons between the two transmit antennas, four transmit antennas with open loop and two phase feedback schemes.

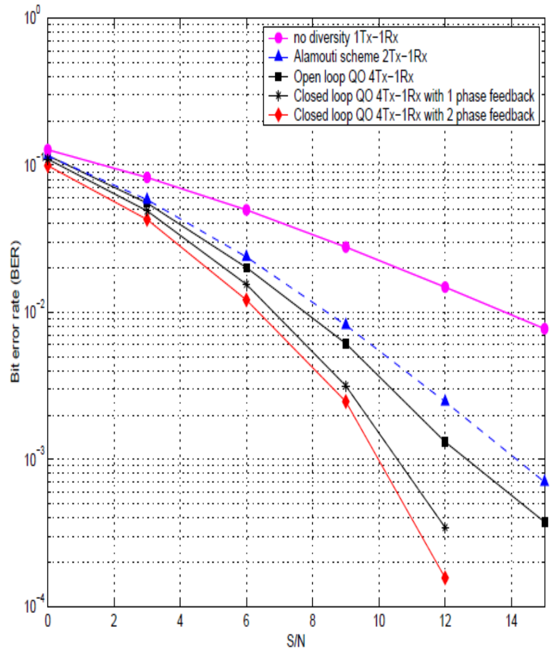

Fig 3: The BER performance comparisons between the two transmit antennas; four transmit antennas with open loop, two phase feedback scheme and one phase feedback schemes.

VIII. CONCLUSION

The proposed closed loop quasi-orthogonal space frequency block code-OFDM can achieve both full code rate and full diversity. By using antenna selection method and phase rotation method, we can minimize the or diagonal terms of the matrix

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BIOGRAPHY

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